

U.S. Serial No. 10/771,919
Reply to Office Action of: September 7, 2007
Family Number: P2003J016-US3

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II. AMENDMENTS TO THE CLAIMS

1. (Currently Amended) A steam reforming and high temperature water gas shift process method for producing high pressure hydrogen comprising:

steam reforming a hydrocarbon during the reforming cycle in a pressure swing reformer, by

(a) introducing at least a portion of said hydrocarbon along with steam and optionally CO₂ through a first end of a first zone having a first volume containing bed packing materials and catalyst to produce a synthesis gas product,

(b) passing at least a portion of the product of step (a) to a second zone having a second volume containing bed packing materials, and transferring sensible heat from the product to the packing materials,

Where each of steps (a) and (b) are done at a space velocity C_1 GHSV of at least 1000 hr⁻¹ as calculated using a combined volume of the first and second zones, and the reforming being conducted at high pressure and under temperature conditions sufficient to provide a synthesis gas stream at a temperature substantially in the range of temperatures used in the high temperature water-gas shift reaction;

subjecting the synthesis gas to a high temperature water-gas shift reaction to provide a multi component product gas stream enriched in hydrogen;

separating high pressure hydrogen from the multi component product gas stream;

combusting a fuel and oxygen in the regeneration cycle of the pressure swing reformer at a pressure lower than that used in the reforming cycle thereby providing temperature conditions sufficient for the reforming cycle and generating a flue gas exiting the reformer.

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2. (Original) The method of claim 1 wherein reforming pressure is in the range of 10 to 100 bar.

3. (Original) The method of claim 2 wherein sufficient fuel and oxygen are combusted in the regeneration cycle to generate a flue gas exiting the reformer at a temperature in the range of about 300°C to about 600°C.

4. (Original) The method of claim 3 wherein high pressure hydrogen is separated from the multi component gas stream by subjecting the multi component gas stream to a pressure swing adsorption process whereby components other than hydrogen are substantially adsorbed thereby providing high pressure hydrogen.

5. (Original) The method of claim 3 wherein reforming temperature conditions provide a synthesis gas in the temperature range of about 220°C to about 400°C.

6. (Original) The method of claim 3 wherein the flue gas is at a temperature of about 400°C to about 500°C and is used to generate steam for the steam reforming cycle.

7. (Original) The method of claim 6 including recovering absorbed components from the pressure swing reformer and introducing at least a portion as fuel into the pressure swing reformer during the regeneration cycle.

8. (Original) The method of claim 7 including recycling a portion of the flue gas to the pressure swing reformer during the regeneration cycle.

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9. (Original) The method of claim 1 wherein the oxygen in the regeneration cycle is provided as compressed air from a gas turbine.

10. (Currently Amended) A method for producing high pressure hydrogen comprising:

(a) passing a feed stream under high pressure conditions and comprising a hydrocarbon and steam through a first zone containing packing materials and a steam reforming catalyst at an elevated temperature to produce a high pressure synthesis gas stream;

(b) passing at least a portion of the synthesis gas stream of step (a) through the first end of a second zone containing bed packing materials at a temperature lower than the first zone thereby transferring sensible heat from the product to the packing material in the second zone and providing a high pressure synthesis gas at a temperature approaching that of the packing material at the second end at a space velocity C_1 GHSV of at least 1000 hr⁻¹, and;

said steps (a) and (b) being conducted at conditions sufficient to provide a synthesis gas at said second end of said second zone in the range of about 220°C to about 400°C;

(c) removing substantially all of the high pressure synthesis gas from the second zone and introducing said gas into a high temperature water-gas shift reaction zone to provide a gas stream enriched in hydrogen;

(d) passing the hydrogen enriched gas stream through a hydrogen separation zone to separate high pressure hydrogen;

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(c) removing high pressure hydrogen from the separation zone;

(f) introducing a fuel and an oxygen containing gas at a pressure lower than in step (a) into the second end of the second zone for combustion and passage through said second and first zone thereby heating the first zone to reforming temperatures and creating a flue gas which exits through the first end of the first zone.

11. (Original) The method of claim 10 wherein the hydrogen separation zone is a pressure swing adsorption zone whereby substantially all of the components of the product gas stream other than hydrogen are adsorbed.

12. (Original) The method of claim 11 wherein the high pressure conditions are in the range of about 10 to about 100 bar.

13. (Original) The method of claim 12 including purging the pressure swing adsorption zone to provide a purge gas stream and introducing at least a portion of the purge gas stream as the fuel in step (e).

14. (Original) The method of claim 13 wherein the regeneration is conducted under conditions sufficient to provide a flue gas having time-average temperature range of about 400°C to about 500°C and the flue gas is passed through a heat exchanger to generate steam for reforming step (a).

15. (Original) The method of claim 14 wherein at least part of the flue gas passed through the heat exchanger is recycled to the second end of the second zone during regeneration.

16. (Original) The process of claim 10 wherein the oxygen containing gas of step (f) is provided as compressed air from a gas turbine.

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17. (Original) The method of claim 10 wherein the packing material of said first and second zones are composed of materials selected from the group consisting of magnesium aluminum silicates, aluminum silicate clays, millite, alumina, silica-alumina, zirconia and mixtures thereof.